subject, the true mathematical expression for the velocity of the wave in terms of that of the molecules of the gas has been determined by Prof. Maxwell. The expression is—Velocity of wave equals $\frac{\sqrt{5}}{3}$ into the velocity of the molecules. This expression requires a slight additional correction in the case of most gases, owing to the movements of *rotation* developed at the collisions of the molecules, depending on their more or less irregular shape, which rotation calculably must delay the wave to a certain extent. According to the experimental results of Kundt and Warburg, the above expression for the velocity of sound in terms of that of the molecules holds exactly true (without correction) for vapour of mercury (whose molecules, it might perhaps be remarked, are simple or monatomic). The slight deviations from the above constant for the velocity of the wave that one observes in fact, are quite consistent with what one would expect from theory.

13. It may be observed that all the usual apparatus for illustrating sound-waves of course applies to the kinetic theory, as such apparatus is only intended to show the effect produced on the *mass* of air, or the condensations and rarefactions, without exhibiting the molecular mechanism that underlies it. A true view of the mode of propagation of the wave and the manner in which the condensations and rarefactions are produced at its passage, can only be obtained by visualising the fact that the molecules of gas are *in motion* in the normal state of the gas, in accordance with the accepted kinetic theory of gases.[1]

14. The kinetic theory thus reduces the conditions on which the velocity of sound in a gas depends to *one*, viz., the *velocity of the molecules of the gas*. It is not, however, this simplification alone that should recommend it, for it is not a mere question of choice or preference of one view over another, but a question of *fact*. For a theory of the conditions physically affecting the velocity of sound and its mode of propagation that may apply to one view as to the constitution of a gas (viz., the old view where the molecules are supposed *at rest*), cannot possibly apply to the diametrically opposite view of gaseous constitution represented by the accepted kinetic theory. It would appear desirable and fitting that the kinetic theory, having been applied so generally in other respects, should find a general application to so important and fundamental a fact affecting a gas as the propagation of sound in it.

15. Since the *physical basis* of a system is admittedly the most important of the whole, it would appear reasonable to expect that the investigation of problems in acoustics might gain by regarding the propagation of sound on the true physical basis represented by the accepted kinetic theory of gases; or by taking a true physical basis to ground the investigations upon, instead of one (based upon the old view of gaseous constitution) that admittedly does not harmonise with the facts.

NOTE.—It has recently come to my knowledge that two papers have been lately published on this subject, one by Prof. Roiti, of Florence (*Nuovo Cimento*, 1877), the other by Prof. J. H. Hoorweg (*Archiv Néer.*, xi., 1876), a brief abstract of which also appears in *Beiblätter zu den Annalen der Physik und Chemie* (vol. i. part 4, p. 209, 1877). Though the latter of these papers appears to precede mine (*Phil. Mag.*, June, 1877), I may add that a sketch of the same theory appears in a little book ("Physics of the Ether," E. and F. N. Spon), published by me in 1875. There is also an interesting paper by Mr. J. J. Waterston (*Phil. Mag.*, 1859, supp. to vol. 16), in which he proposes to illustrate the propagation of waves by a system of spheres, but he does not go into the explanation as to how the motion he assigns to the spheres can properly represent the case of a gas in its normal state. There are, nevertheless, points of interest in the paper.

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[1] It would appear not unreasonable to conclude that a realisation of the *molecular basis* underlying the propagation of sound, according to the accepted kinetic theory, might be able to throw some light on the investigations in connection with the telephone and other allied instruments, where the *molecular basis* of the phenomena would seem to be the essential point to be considered.

WHAT IS MORPHOLOGY?[1]

IF those of us who have laboured up the hill of life revert to the studies of our youth, I think we shall not remember to have heard our teachers speak of the "Morphology of Animals." I cannot remember when or where I first met with the word; although the idea itself with regard to plants, has been familiar to me for nearly forty years, that is, since the time when I became possessed of "Lindley's Introduction to Botany;" but he used the term "Organography." The term "Morphology" was used by Schleiden in his "Principles of Scientific Botany" at least thirty years ago; and I may say in passing that the study of that work was one of the best preparations I received for the work I have undertaken since.

A comparison of the mode in which both plants and animals are developed was suggested to me, if not for the first time, yet then with new force, by reading Johann Müller's "Physiology of Man;" especially in the part on Generation, and more especially in his statement of, and criticisms upon, Caspar J. Wolff's "Theory of Generation," which was published at Halle in 1759. The very mention of this date is interesting, for this is evidently the time, and this work of Wolff's was surely the work, which suggested to the great, rich mind of Goethe the idea of an underlying unity amid all the diversity of vegetable and animal forms. How fruitful this conception of the simplicity and unity of vegetable and animal patterns has been, I need not tell you; for more than a century it has been yielding precious and ever increasing results. It was natural, therefore, that a division of biology so new and so fascinating, should gain for itself a name: and as naturalists had been from time immemorial familiar with the *metamorphosis* of certain types, the term "morphology" which especially treats of such changes in the individual life-history of a plant or of an animal, was natural, easy, and appropriate.

The *à priori* dreams which made the study of vertebrate morphology appear transcendental, and indeed gave it that title as a cognomen, caused great loss of time and of talent: and if Prof. Huxley had done nothing else whatever than dispel the glamour of these dreams, he would have deserved well of his age. His "Croonian Lecture," delivered at the Royal Society about twenty years ago, was as "a trumpet that gives a certain sound;" the dreamers awoke from their dreams, and became the workers, who since that time have wrought with labour and travail night and day. But the science of morphology, which had become an elegant pastime here, had long before Prof. Huxley's time found a noble band of workers in Germany; from that land came the dream; in that land arose the workers; the labours of Rathke, von Baer, and Reichert were ready to the hand of our biological reformer. After these, who were the chiefs of the band, came others, all men of name and renown; "but they attained not to the first three."

My own indebtedness is primarily to Johann Müller, who in his "Physiology of Man," already referred to, gave such an excellent abstract of the labours of the embryologists, his countrymen. I ought not to forget his lamented translator, Dr. Baly; for in the original Müller's work was a sealed book to me, and indeed would be now.

The fact that all organic beings pass through various stages, and run a certain round of life, is now becoming

[1] The first of a course of lectures "On the Morphology of the Batrachia," delivered at the Royal College of Surgeons, by Prof. W. K. Parker, F.R.S.

generally known. In the midst of the very beginnings of life the unspeakably minute monads, as the beautiful researches of Dallinger and Drysdale show, pass through several stages in their individual life-history. All the intervening living forms, between the monad and the man pass through several stages. The "Seven Ages" attributed by the poet to man are preceded by twice seven stages.

In all times the insects showed the wonderful working of the morphological force; the poets noticed these facts and sang of them; the philosophers, also, and reasoned upon them; but it was left for us to learn that these facts are not unique, but universal. Nevertheless, "the bee who is small amongst those that fly, and yet her fruit is the chief of sweet things," and that still smaller creature, the wise-hearted ant, architect, soldier, and lawgiver; these, and the other members of the insect-class, are metamorphosed *openly*. So, also, are the amphibia among the vertebrates, for instance, the frog and the newt, whose changes of form are so familiar to us. Still, for the most part, in the vertebrata "these things *are* done in a corner;" their most important changes of form are hidden from unassisted vision; to search out those secrets is the work of the morphologist.

Here, however, I will let "that old man eloquent"—Lord Bacon—speak for me; he says that Solomon, who was a great example with him, did "compile a Natural History of all verdure, from the cedar upon the mountain to the moss upon the wall (which is but a rudiment between putrefaction and an herb), and also of all things that breathe or move. Nay, the same Solomon, the king, although he excelled in the glory of treasure and magnificent buildings, of shipping and navigation, of service and attendance, of fame and renown, and the like, yet he maketh no claim to any of those glories, but only to the glory of inquisition of truth; for so he saith expressly, 'The glory of God is to conceal a thing, but the glory of the king is to find it out;' as if, according to the innocent play of children, the Divine Majesty took delight to hide his works, to the end to have them found out; and as if kings could not obtain a greater honour than to be God's playfellows in that game; considering the great commandment of wits and means, whereby nothing needeth to be hidden from them."

It seems to us now a little thing for a great mind meditating upon the form of a vertebrated animal to think that the axial structures should pass into the skull, when the main nervous axis so manifestly expands to become the brain. Yet men were held in bondage from generation to generation by the force of mere teleological ideas, that do but as Bacon expresses it, "Slug and stay the ship from sailing." In one place he compares people who will have all these meanings and ends of things at any cost, and who cannot bear to look at things in the "dry light" of their efficient causes, to those low and sensual people of whom one reads in holy writ, who accounted the manna as poor, thin diet, and clamoured for the onions, the leak, and the garlic, that flavoured the flesh-pots of Egypt. Now, however, the study of structures, according to their mere uses, and the imagining of ideal exemplars, these modes, the one imperfect and the other illusory, are giving place to the observation of the rise and progress in life of living creatures.

This rise and progress may be traced *gradationally*; which is a tracing of form after form in the adult animals existing at the present time; a most profitable study surely. To this has been added (within the last century almost) the investigation of forms that have become extinct; here, in "palæontology," we come athwart forms that are lower in type than their nearest relatives now living. Lower, and more generalised are they: and thus the mind is led to look towards the causes that have operated in the extinction of the old, rough, archaic forms, and the production or creation of the "lovely living things" that now adorn the earth. These are very often smaller, and, as a rule, more specialised in all respects, beautified, refined, and elevated in type beyond anything that could have been seen in their predecessors or progenitors. But that which both the gradationalist and palæontologist want, is a knowledge of the *development* of the types, their life-history, indeed.

Here is the work, this is the labour! Our immediate fathers began it; we have entered into their labours; but our children's children will have their hands full, not for one, but for many generations. Were this done, could we describe in detail the rise and progress of every part, and of every organ in the structure of any form in the genera, families, orders, classes, and sub-kingdoms of the animal kingdom; we might then come to some conclusion as to the relations of these various forms, and make some safe guesses as to how they have arisen. Nevertheless, if we cannot do all, that is no reason why we should do nothing, and stand as men who cannot find their hands; the light is breaking in upon us already; albeit, the work has but just been begun. The relations of living forms to each other—even in the adults—and the relations of extinct to living types; these flowers of science are opening and displaying their beauties to patient observers. We are now not merely considering the relations of the various vertebrate classes to each other, or of the various articulate, or molluscous, or radiated classes, within their own special circle; but embryology is leading us to the origin, as it were, of each great primary group, and of the branching off, so to speak, of each great group from some common stock.

However admirable in form and action *man* now is, he will soon, as a *vertebrate*, be ready to call the worm his sister and his mother; for his group is being set side by side with the worm-group—with the living forms from which sprang the "poor beetle," and the labouring ant. Indeed, as seven cities claimed Homer, so several *invertebrate* stocks now claim to have given birth to the noble *vertebrata*. The noisiest claimants are the *worm* and the *ascidian*—that poor relation of the oyster; by some this is thought to be madness, but there is method in it. I will now quote part of an article which appeared in the *Nineteenth Century* for December last, on "Recent Science." The writer is giving an account of Prof. Reichenbach's beautiful researches into the embryology of the common freshwater cray-fish, and then he goes on to compare the development of the nervous axis both in the invertebrata and vertebrata.

"Until quite recently the manner in which the central nervous system arises has always been considered as one of the most important distinctions between vertebrate and invertebrate animals. In the former, at the period when the embryo is a small three-layered patch on the surface of the egg, a longitudinal groove appears, the side walls of which, meeting above, inclose a tube lined by the epiblast. From the epiblastic cells thus shut off, the whole brain and spinal cord are produced, together with the roots of the cranial and spinal nerves, as the recent observations of Mr. Balfour [1] and Dr. Marshall [2] have shown. In the invertebrata, on the other hand, it was always supposed that the nerve-cord was produced from the middle layer of the embryo, or mesoblast; but this has been shown not to be the case, for it has now been proved that, in many of these, the nervous system arises from a thickening of epiblast, which only differs from the corresponding structure in vertebrata by the fact that it is not sunk in a groove. But the relation, in this respect, of the two great groups of the animal kingdom has never been more clearly brought out than in Reichenbach's [3] paper. He shows not only that the nerve-cord is a product of the epiblast, but that it arises from the cells lining an actual

[1] "On the Development of the Fresh-water Crayfish." (Die Embryonanlage und erste Entwickelung des Flusskrebses.") *Zeitschrift für wiss. Zool.* xxix., Bd. 2, Heft, July, 1877.
[2] *Phil. Trans.*, vol clxvi., and *Journ. of Anat.*, April, 1877.
[3] *Journ. of Anat. and Phys.*, April, 1877.

groove—a groove having precisely the same relations, and in one part of its course being nearly as deep, as the 'medullary groove' of a chick or a tadpole. He also shows that the eyes are formed not, as is usually stated, as elevations, but as depressions in the epiblast; the cells lining these depressions becoming connected with those of the first ganglion of the nerve-cord. Here again is a remarkable resemblance to vertebrates, in which the organs of the higher senses always originate as involutions of the surface-layer" (page 896).

I have thus passed insensibly from the meaning to the aims of morphology. I trust you will agree with me that it is "a topmost fruitful bough" of the great tree of modern science; it is certainly fuller of buds than of flowers, for now is its early spring only. Kindly attend whilst I open a bud or two to show you what the flowers promise to be.

The ends and aims of *morphology* are different from those of *physiology; histology* may be said to be equally related to each and ancillary to both. The study of one branch seems to ask in its workers for an innate fitness for the one rather than for the other. One man sharply questions the *why* of nature; the other patiently searches after the *how*. *Morphology* asks for one who can work and wait in silence year after year; and his qualities have need to be those of quick insight, combined with the most phlegmatic laboriousness. Here, in this case, *natural* qualifications are of more importance than those which can be acquired. But the physiologist sharply asking *why* needs to be trained for his work; he must be a mathematician and a chemist as well as an anatomist; ready action and cunning inventiveness are most needed in him; a seeing eye, a copying hand, and a somewhat imaginative nature; these are the qualifications asked for in the morphologist. Delight in living forms and their transformations shows itself very early in us all; morphology is *æsthetic* before it is *scientific;* it becomes *scientific* as soon as it is *comparative*. The morphologist is nothing if not comparative; the development of accurate observation, combined with ready and constant comparison and unconscious classification—these are the necessary elements in the morphological worker.

The group of animals to which we belong—the vertebrata—considered as to their skeletal morphology, form alone a wide field; "there is yet much land to be possessed." In that division of a subdivided science I have chosen for time and for work's sake mainly the head; for in it are to be found the most intricate interweavings, the hardest knots of nature. For a time, for work's sake, one kind of head is enough; if all the parts are to be considered in their origin and relations, in their changes and development. For the solid and supporting parts of the *building*, so to speak, are to no purpose, have no meaning, if we could possibly forget their contents and their outgoing and overlying parts.

Considering the great complexity of structure in the highest types, the mind casts about to see if there be no similar forms of living creatures in which the structural problems are simpler. As man does not stand alone, but is merely—in respect of his lower nature—one of a large series of living forms, something, surely, may be learned of him, collaterally, and from below, by seeking what may be seen in the types that come nearest to him. Feeling our way down among the branches of the great vertebrate life-tree, we come to forms somewhat simpler, indeed, but formed on the whole on the same pattern, and having on the whole the same mode of embryogeny, and no real break occurs, even among living types, until we have passed the lamprey and his companions. Searching downwards, however, from any culminating type of mammal, we shall come to no form directly underlying them until we are among aquatic creatures; the birds, lying over the reptiles, belong to another "leader" in the life-tree.

Do but consider what a manufactory, what a laboratory, what a temple (if I may so speak) the head is! Yet it and all the body, of which it is the chief part, is developed vegetatively—its *growth* is as the growth of a plant, but its *architecture* stains the pride of all the glory of human skill. Man, not *structurally* only, but *socially*, also, is both husbandry and a building. And as the forces that bind the units of society together are the same as those that perfect the individual as such; so, also, is it in that which enclothes man and brings him into conscious relation to his fellows. The forces that work in the elementary parts are the same as those that work in the whole to make it one whole. The body is compacted together by that which every cell, every tissue, and every organ supplies; "according to the effectual working in the measure of every part" does it live, grow, and build up itself, and perform its wondrous and inimitable functions.

For a century past the thinking mind has been gradually trained to consider the earth, which is our temporary home, as a *development*, as being in a state now very different from that which it had at first, as having undergone, not one, but a thousand changes. Every one, now, knows that the earth did not "rise like an exhalation," and immediately assume its present form, wear its present robes, carry its present living forms; but that, during *Eonian days*—immeasurable secular periods—the face of the earth has changed as much as the face of a man changes during the "seven ages of his eventful history." It will take some time to bring the mind face to face with *our* facts; the thinkers as well as the unthinking will be slow in parting with the old cherished idea of the sudden apparition of a perfect man upon the earth, and the more because this *seems* to be the teaching of the most venerable records of history; which, indeed, ought to be *sacred* to us, if for no other reason than their undoubted antiquity. Those most venerable records have not suffered now that we get a Pisgah-view of the earth's development; they will not suffer from any doctrine of the slow development of man.

I had to speak of the *aims* of morphology; its highest aims are to be able to read off the archaic writings in which the members of man were in olden times written; to decipher the first promise and prophecy of his organic life in its initial letters up to the characters that express the form of the jointed worm, and to see the form of the jointed worm exalted into the fulness of the form of man. Yet we know of nothing but the sequences and results of the morphological force; we know absolutely as much of the nature of the human soul as of the nature of protoplasm, and nothing of either. The morphologist, as such, for the time, is like Gallio, he "careth for none of these things;" he refuses to be hindered with side-questions, however grave and important; his motto is, "this one thing I do." His work is to trace the *germ* into the *adult* or *germ-grower;* to scale every stage and step of a living creature's life; to map out each form, passing into succeeding forms, until the perfect form appears.

The ladder of man's life reaches up to the highest heaven of organic beauty; that of the horse, the ox, and the lion stops far short of this height; yet are they all perfect after their kind. You will see at once that man is an animal *plus* something that has made it possible for him to become "in form and moving so express and admirable; the beauty of the world, the paragon of animals!" Prof. Flower will show you what a poor thing man is when that which makes him *man* is arrested or suppressed; you will then "look on this picture and on this," on man in his highest development; his outward form corresponding to the power and excellence within; and on man undeveloped, brutal, foul in face, and fouler still in life.

W. K. PARKER